Final Technical Report
## Galactic Winds and Intragroup Medium Energetics
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The main objective of this proposal was to study the metallicity distribution of HCG 97 with the goals of determining the SN Type enrichment, the strength of galactic winds and how it impacts on the evolution of cluster's ICM within the framework of hierarchical formation scenarios.

Objectives and Methodology - SNe Ia and II produce different amounts (yields) of different elements. Therefore, we can use elemental abundance ratios to determine the contribution from SN Ia and II to the X-ray emitting plasma. For example, classical SN Ia models predict that the ratio of O to Fe abundances (by number normalized to Solar) should be ~ 0.04 while SN II models predict the same ratio to be ~ 3.8. So, if the measurement of the O/Fe ratio in the IGM is 0.5, it would mean that the SN Ia iron mass fraction is 88%, and the rest (~12%) would have been produced by SN II. Knowing this fraction and the gas mass we can directly estimate the average SN Ia and II rates necessary to produce the observed amount of metals and also the strength with which metals were injected into the IGM.

There are two main difficulties involved in the determination of the SN Ia/II contamination of the intragroup gas in CGs. First one needs to know the theoretical SN Ia/II elemental mass yields accurately. Although there is good consistency among different SN models in predicting the yields of some elements (e.g. Si), this is not always true for other elements (Gibson et al. 1997). To overcome this difficulty one needs to estimate the SN Type contamination using several different elements and check for self-consistency (Dupke & White 2000a,b). This procedure has been applied successfully before for clusters and can produce accurate results, even when some abundances are not well constrained.

HCG 97 (z~0.022) is a relatively bright compact group that has two Es, two Ss and a S0. ROSAT analysis revealed a mild temperature decline from ~1 keV in the center to ~0.6 keV at r>6'. The velocity dispersion is also somewhat lower (by~40-50%) than that expected from its temperature, implying that the IGM has been heated by winds. After subtracting flared regions, we were left with nearly 27 effective ksec of exposure for the MOSs and 25 ksec for the PNs. The cleaned images for MOS1, MOS2 and PN and their light curves are shown below:
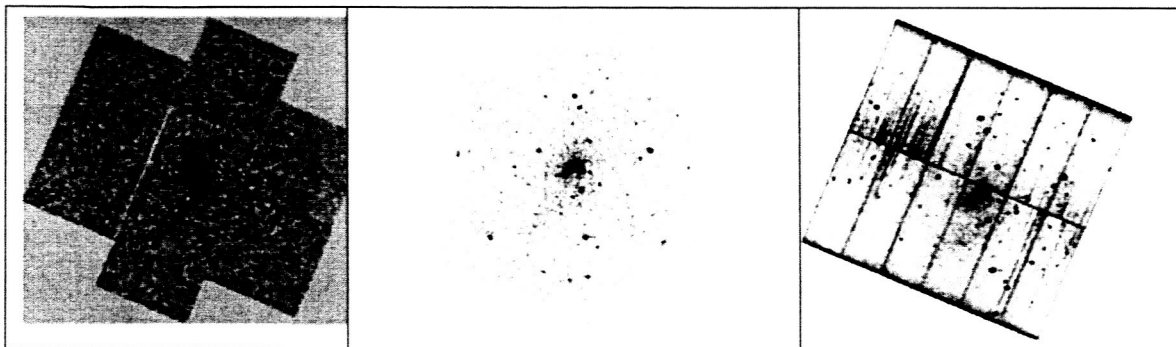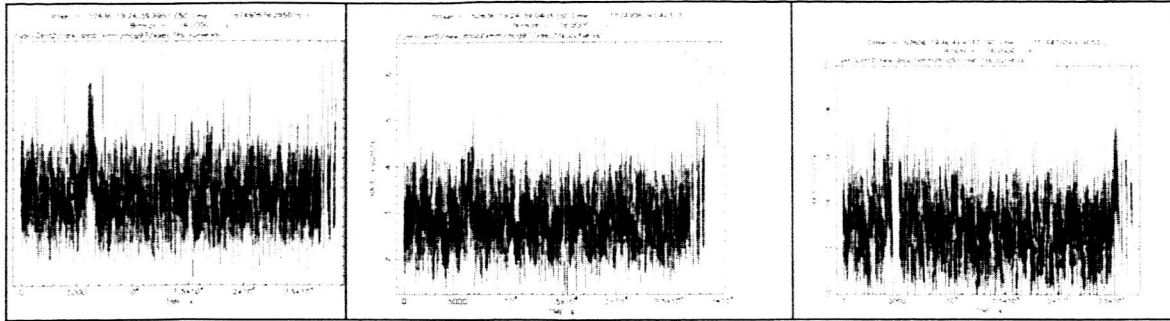
The results from spatially-resolved spectroscopy and subsequent analysis of abundance ratios indicate a dominance of SN Ia material throughout the group. Below we show the X-ray spectrum of the region indicated on the left image by a circle, with the central source excluded.
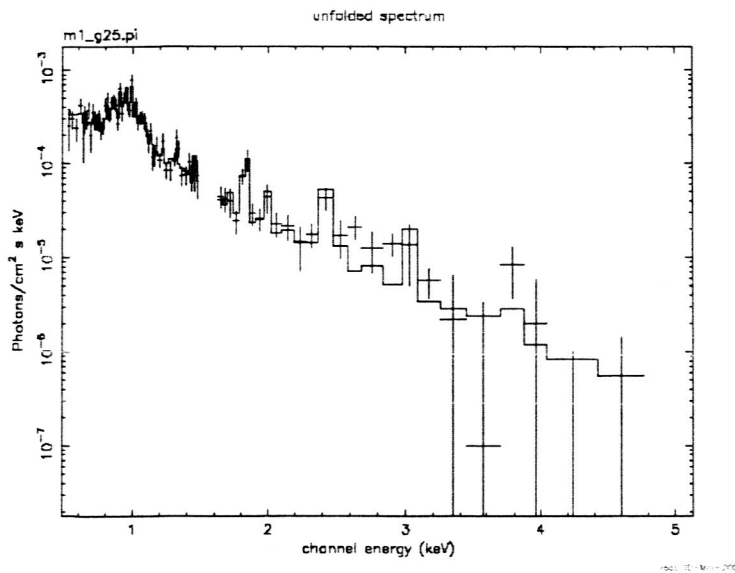
Unfolded spectrum of HCG 97 with MOS1. The central galaxy is excluded. The spectral model is an absorbed (WABS) thermal (VAPEC) with variable abundances. The Hy column density is fixed at the Galaxctic value.

In the Table below we show the best-fit values for individual abundances and abundance ratios as well as the corresponding SNIa Fe mass fraction as derived from the abundance ratios using the SN yields of Nomoto et al. 1997. With the exception of an anomalously high abundance of Silicon the ratios indicate an overall dominance of SN Ia material. The weighted average is 71 ± 12 % SN Ia dominance. This is consistent with scenarios where SN II ejecta from protogalactic winds having escaped the shallow gravitational potential of the group and that energy injection from less vigorous SN Ia winds should have a higher impact on these systems, as it has been indicated by previous X-ray observations. However, the values are still consistent with significant SN II contamination, indicating that the group has not lost all of its protogalactic wind enrichment or that secondary SN II winds are happening. The presence of X-ray plumes in the image may indicate that the galaxies in the group may currently be strongly interacting.

		ratio/Fe	SN Ia Fe Mass Fraction
Temp (keV)	0.98 ± 0.04		
Oxygen	0.09 ± 0.09	0.59 ± 0.61	85 ± 15
Magnesium	0.26 ± 0.14	1.76 ± 1.04	55 ± 26
Silicon	0.41 ± 0.10	2.73 ± 0.96	30 ± 30
Sulfur	1.01 ± 0.33	6.83 ± 2.79	
Iron	0.15 ± 0.04	1	
Nickel	0.92 ± 0.55	6.15 ± 3.96	100 ± 80

Technically there were two concerns that required a significant amount of effort. The first technical uncertainty that has drawn significant attention from the scientific community is the proper background subtraction with XMM. To date there is no consensus about a "proper" background subtraction method and we have used several different data reduction techniques to subtract backgrounds, including local, blank-sky, double-subtraction as well as different methodos used by other groups. We believe that the main results that we described above are weakly dependent on background issues.

The second concern that we are dealing with is the proper separation of galaxy and point source contamination from true intragroup medium. An approved Chandra observation of this group will allow us to separate the two components and we will be incorporating the results of that observation in our results before submitting the final results for publication.

Preliminary results (below) were presented in the High Energy Astrophysics Division of the AAS in August 2004 where we compared the differences of metal enrichment between groups and clusters.